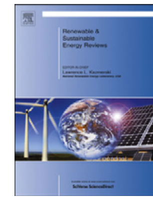
Renewable and Sustainable Energy Reviews 16 (2012) 5535–5544

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser



Temporal change analysis of public attitude, knowledge and acceptance of hydrogen vehicles in Greater Stavanger, 2006–2009

Ari K.M. Tarigan *, Stian B. Bayer

International Research Institute of Stavanger (IRIS), PO BOX 8046, 4068 Stavanger, Rogaland, Norway

ARTICLE INFO

Article history:
Received 1 March 2012
Received in revised form
27 May 2012
Accepted 28 May 2012
Available online 9 August 2012

Keywords:
Hydrogen vehicle
Hydrogen fuel
Knowledge
Environmental attitude
Public acceptance
Greater Stavanger

ABSTRACT

This study examines the trends of public opinions concerning the introduction of hydrogen vehicles in Greater Stavanger as well as public attitudes towards the natural environment over the course of the three-year period. This study is based on two surveys of the hydrogen highway project (HyNor) which were collected in the Greater Stavanger region, the west coast of Norway, between 2006 and 2009 ($n=2000$). The results of the study highlight that – despite an increased awareness of hydrogen vehicles – the proportions of those with pro-environment attitudes who support hydrogen vehicles' introduction decreased between 2006 and 2009. The results reveal that knowledge about sustainable environment can affect hydrogen energy's acceptance whereas the level of pro-environment attitudes can increase not only public acceptance of hydrogen vehicles, but also people's willingness to pay for hydrogen fuels. These results were consistently found throughout the observed periods, based on the Greater Stavanger's case. A set of recommendations was discussed to improve public acceptance of hydrogen vehicles, and the next avenue of research regarding analysis of public acceptance and awareness about hydrogen vehicles was proposed.

Contents

1. Introduction

Hydrogen vehicles along with other green technology features, such as electric, biogas and solar-powered vehicles, have been seriously considered for sustainable urban mobility [1–4]. As argued by environmentalists and urban transport scholars, such uses of these vehicles can reduce air pollution created by the intense use of fossil-based fuels in the road transport sector as well as mitigate fossil energy shortages that might exist in the future. It is further suggested that shifting conventional vehicles with sustainable fuels for a long-term effort can produce significant contributions in preventing global warming and other atmospheric deteriorations [5–9].

* Corresponding author. Tel.: (+47) 51875128; fax: (+47) 51875200.
E-mail addresses: ari.tarigan@iris.no, a.k.m.tarigan@gmail.com (A.K.M. Tarigan).

1364-0321/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2012.05.045

During the last two decades, significant attention has been focused on increasing the share of hydrogen vehicles on urban roads. For example, a proposal from the European Commission for energy and transport established a goal to increase the proportion of hydrogen vehicles to 25% of all vehicles in the European market by 2030 and 35% by 2040 [10]. In North America, state governments (e.g., California, Connecticut, New York and South Carolina) and universities (e.g., UC Davis and UC Berkeley) have spent billions of dollars on hydrogen energy projects [11,12]. Both parties are currently implementing various strategies for demonstrations, education, public outreach and market deployments of hydrogen vehicles in order to achieve the greatest likelihood of success for such energy introduction efforts. The world's leading auto manufacturers and energy companies have also been actively involved in producing hydrogen fuel and providing it into the market. For example, in Germany, a public–private consortium has sought to address the potential needs of hydrogen fuel by targeting the construction of 1000 hydrogen refuelling stations. As part of this goal, the German government has injected at least 1.4 billion euros into supporting various development steps in pursuit of new innovations related to hydrogen vehicles [13]. Such evidence clearly shows that key players in Germany are moving forward in anticipation of future needs related to sustainable vehicles for local and global markets.

In Norway, hydrogen energy developments have been extensively discussed and researched by the authorities, energy scientists and industries, leading to the first hydrogen highway project (HyNor) being established in 2003. This project is recognised as part of a broader agenda in the Nordic region aimed at introducing, socialising and implementing hydrogen energy features for motorised modes through the Scandinavian Hydrogen Highway Partnership (SHHP) involving Norway (HyNor), Sweden (Hydrogen Sweden) and Denmark (Hydrogen Link). The HyNor project's primary goals are (1) to introduce a hydrogen road network from Oslo and Stavanger, including refuelling stations; (2) to extend the coverage of hydrogen vehicles' introduction, involving other major Norwegian cities, followed by the capacity improvement of the present refuelling stations; and (3) to promote a hydrogen road network in Scandinavian regions, connecting major cities in Sweden, Denmark and Norway through the SHHP network [14,15].

Norway's first hydrogen fuelling station was formally put into operation in August 2006 as part of the HyNor project. This refuelling station was developed for delivering 350 and 700 bar hydrogen as well as natural hythane, a mix of natural gas and hydrogen [15]. This site is located within an industrial neighbourhood of Greater Stavanger—namely, the Forus area. The hydrogen refuelling station was developed and is owned by Statoil (a state-owned oil company) and is located adjacent to the conventional refuelling station. Four Toyota Prius hydrogen cars were used in Greater Stavanger when the project was first started; by 2011, 15 Toyota Prius and 4 Mazda hydrogen cars were in use in Norway. As briefly described by the HyNor project's reports, several new hydrogen vehicles have been operated on Norwegian roads (e.g., 10 Mercedes Benz, 5 Think City, and 2 Hyundai hydrogen cars). Based on our observations in 2009, local residents welcome the introduction of hydrogen vehicles as a significant number of the respondents in Greater Stavanger consider hydrogen to be one of the most promising fuels for the future [16].

It should be further noted that, along with the implementation of hydrogen energy for motorised modes in Greater Stavanger, other major cities in Norway (e.g., Bergen and Oslo) have developed similar efforts, introducing other modes of transportation relying on hydrogen fuels (e.g., public bus and passenger ferry). Moreover, hydrogen energy development efforts are being studied for other purposes, such as heating systems for buildings and housing.

2. Past studies and research objectives

In addition to extensive engineering development efforts and technical innovations of hydrogen energy features [17,18], comprehensive studies focusing on the public's acceptance of hydrogen vehicles and their reaction to the different aspects of the technology have recently been carried out. As suggested by Schulte et al. [19] and Huijts et al. [20], a comprehensive understanding of hydrogen knowledge, perception, attitude and acceptance towards hydrogen vehicles is strongly beneficial for increasing the market's share of hydrogen use and purchase. These researchers argued that gaining crucial information about advantages and barriers of renewable energy developments, as expressed by the public, can be utilised for future improvements of the technology. Such studies further allow us to comprehensively examine the characteristics of those who are likely to support the adoption of hydrogen vehicles and those who do not in society. These characteristics can provide important feedback for addressing specific policy strategies, such as designing an effective campaign of hydrogen energy introductions for those who are most likely to purchase and use the hydrogen vehicles in the future. Furthermore, preparing subsidy scenarios and other incentives will be more powerful if policy makers have a sufficient "map" of technology supporters' profiles.

Past studies demonstrate that social factors such as age, income and education level play a crucial role in determining the propensity of public hydrogen vehicles' support and use [21–31]. For example, Altmann and Gräsel [25], Schmoyer et al. [26] and others indicate that those with higher degree of formal education are more likely to support the technology; this belief is consistent with other renewable energy cases as well, including biogas [32] and electric vehicles. Previous studies further reveal that male individuals are more likely to support hydrogen vehicles than their female counterparts [22,27]. However, the dominant role of males on this issue seems to be less conclusive since other evidence reports that women are cautious about hydrogen energy and aware of the unsustainable consequences of utilising fossil fuels (a set of reviewed studies addressing such issues can be found in Ricci et al. [29], Roche et al. [30] and Sherry-Brennan et al. [31]).

Location and built environment variables can bring further significant implications to the possibility of accepting and using hydrogen vehicles. For example, the location of refuelling stations can influence the public's knowledge and even sense of belonging to the hydrogen energy projects [15,16] as those who live close to the hydrogen refuelling stations may be more familiar with the presence of the hydrogen refuelling stations, making them more likely to support hydrogen fuels. In addition, the long travel distance factor in reaching the hydrogen refuelling stations from users' regular location points (i.e., home and work) can lead to resistance to hydrogen technology [33] as people may have less flexibility for travel when using hydrogen vehicles.

Although a significant consensus exists in the literature about a positive correlation between positive attitudes of sustainable environment concerns and support for the introduction of renewable energy, the effect of greater knowledge on the likelihood of renewable energy support and use varies across studies. On one hand, the results demonstrate that having a sufficient knowledge can lead to support for renewable energy as the public becomes much more aware about the purposes of such efforts. However, other studies have found that sufficient knowledge about renewable energy features has no significant relationship with the decision to support the technology [29–31]. A few studies even found a negative correlation between these factors because the public focuses more attention on the negative implications of the technology developments (e.g., the Heidelberg bomb), causing

people to doubt that safety issues have been fully addressed in energy development efforts [22].

Questions about willingness to pay (WTP) for hydrogen fuel were often included in other studies in order to clarify whether environmental advantages could persuade people to spend extra money on the fuel [11,15,16,23]. For example, one study measured the "money" value of hydrogen fuels based on the total value of hydrogen fuel purchase and the money value of efforts to protect environment by purchasing the fuel. The final value, considering both variables, was defined as WTP for hydrogen fuels. In another group of studies, a direct assessment of WTP was conducted by directly asking how much extra money an individual would pay for hydrogen fuel; the average value of WTP was determined for the entire sample group. In addition, Martin et al. [11] compared WTP among Californians in two cases using the same sample group (before and after direct experience with this vehicle), contributing to the literature regarding the roles of ride experience on WTP change.

In the context of Norway, Thesen and Langhelle [15] investigated public feedback about awareness, acceptability and attitudes related to the development of hydrogen energy when HyNor refuelling stations were first put into operation in 2006. The primary results of their study demonstrated that the respondents had significant environmental concerns and pro-environment attitudes as well as strong public acceptance of hydrogen vehicles. The study further argued that prior knowledge about hydrogen vehicles was key for developing greater support for such technological developments. However, based on a recent survey, Tarigan et al. [16] offered an indication that greater knowledge among Greater Stavanger respondents can imply a lower level of support for hydrogen energy features, particularly when pro-environment attitudes have not changed. Ultimately, the greater the knowledge, the stronger the attitude in support of sustainable environment and hydrogen energy, which may consistently imply greater support for the applications of hydrogen vehicles.

Hydrogen energy and its application in the road transport sector have been actively discussed among the mass media in Norway since the HyNor project was launched in 2006 (see Fig. 1), which may have played a crucial role in influencing changes concerning public knowledge, attitudes and acceptance of hydrogen vehicles and related infrastructures [22]. Such evidence is in line with Thesen and Langhelle's [15] report, suggesting that a great amount of information distributed by newspapers, magazines and TVs can increase hydrogen knowledge, thereby implying a greater acceptance of hydrogen vehicles. Yet doubts have

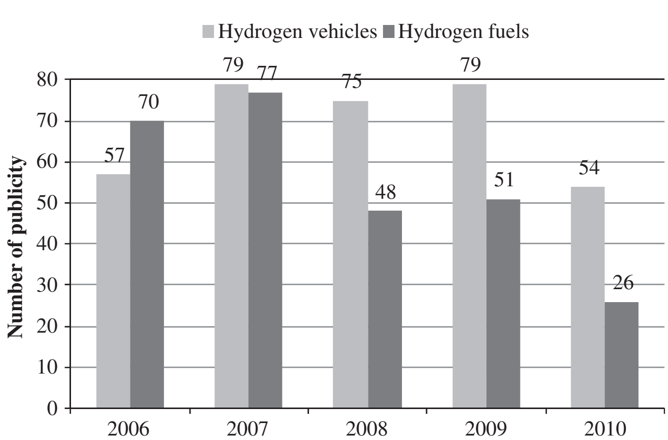


Fig. 1. Number of publications about hydrogen energy and its related applications published by national and local newspapers in Norway from 2006 to 2010 (*Source*: authors' calculations).

emerged about public responses and the temporal trends related to knowledge of, attitudes towards and acceptance of hydrogen vehicles and refuelling stations. For instance, given the great amount of information that has emerged from various means over the last few years, a paradox hypothesis may apply: Greater information about hydrogen vehicles could be leading to sceptical opinions about the future of hydrogen energy as people become more knowledgeable about certain disadvantages of the technology and its potential problems (e.g., high costs of hydrogen energy production, safety concerns and related risks as well as limited availability of refuelling stations). Such effects in turn create greater negative opinions about hydrogen applications, consequently reducing support for this technology. Tarigan et al. [16] stressed this type of possibility, particularly when the public did not simultaneously change their attitudes to support a sustainable environment.

Driven by this discussion, the current paper aims to review the progress and changes concerning public knowledge, attitudes, acceptance and WTP related to hydrogen vehicles' development among the Greater Stavanger individuals ($n=2000$). The study aims to verify how people react to the introduction of hydrogen energy and how such reactions substantially changed between 2006 and 2009, particularly in areas where local newspapers continuously published information about the technology during the observed periods. Consequently, this study employs two sets of data (the 2006 and 2009 data) to uncover the trends in hydrogen knowledge, attitudes and support among the Greater Stavanger samples. The study further differentiates the participants based on those who live very close to refuelling stations and those who live further from the stations in order to capture the influence of the 'not in my back yard' (NIMBY) issue, as highlighted by previous studies [15,16,23].

To the best of our knowledge, only a few previous works have focused on a temporal change analysis of knowledge, attitudes and acceptances related to hydrogen energy features as well as WTP for hydrogen fuels. The closest research design we found is the work of Shaheen et al. [24], which demonstrated the dynamics of drivers' behaviours towards hydrogen vehicles utilising three phases of a survey in California using monthly-based data with a limited sample size. Hence, it is hoped that the current study – with its larger sample size – may be valuable as an opportunity to disseminate the transferability of the results about temporal trends of public knowledge, attitudes and acceptance related to hydrogen energy applications based on an industrialised nation's experience [24]. Moreover, the results of this research will be essential for preparing future strategies and policies in order to generate greater positive support from the market as well as prevent a significant decrease of support for hydrogen vehicles.

The rest of this paper is organised as follows. The data and the description of the sample are elaborated upon in the next sections. The results are then presented. Finally, discussions and conclusions are presented.

3. Data collection

The dataset employed in the study is part of the HyNor research project, which was partially funded by the Norwegian Research Council. The surveys consist of two phases collected during spring 2006 (phase 1) and 2009 (phase 2). The surveys were randomly addressed to 1270 telephone numbers. The second survey approached the respondents based on the same telephone number lists utilised in the first phase. The surveys targeted two groups: individuals living within a 1 km radius of the hydrogen refuelling station (defined as the "Back Yard"

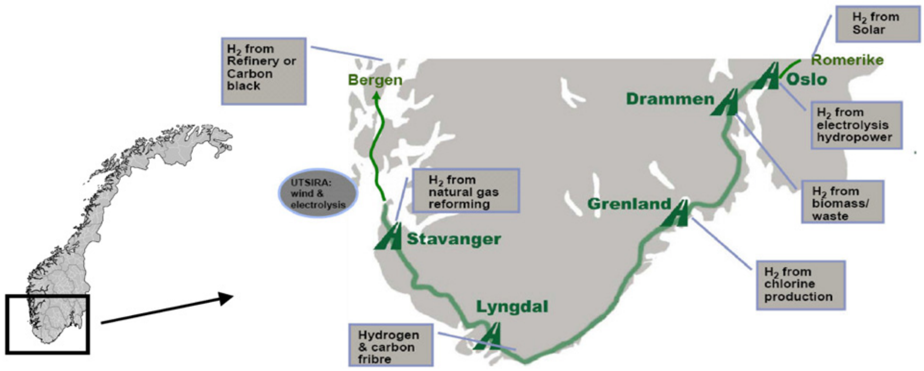


Fig. 2. Major HyNor projects in Norway (*Source*: HyNor).

Table 1
Respondents' characteristics.

	Greater Stavanger			Back Yard		
	2006 (n=600)	2009 (n=600)	Change[a]	2006 (n=400)	2009 (n=400)	Change[a]
Women (%)	55.2	47.8	−7.3	52.0	47.0	−5.0
Age (Mean)	50.9	49.0	−1.8	43.4	45.7	2.3
18–25 (%)	6.0	6.5	0.5	12.3	10.5	−1.8
26–35 (%)	10.7	11.2	0.5	20.5	14.5	−6.0
36–45 (%)	23.5	26.2	2.7	22.5	20.3	−2.3
46–55 (%)	20.5	24.5	4.0	23.3	29.0	5.8
56–65 (%)	20.8	17.0	−3.8	14.8	18.3	3.5
66+ (%)	18.5	14.7	−3.8	6.8	7.5	0.7
Higher degree[b] (%)	68.7	66.8	−1.8	65.3	68.4	3.2
Car ownership (%)	91.2	92.0	0.8	93.5	93.8	0.2
Full-time worker (%)[c]/[d]	71.5	67.9	−3.6	80.0	77.7	−2.3
Petroleum-based worker (%)	27.2	29.7	2.5	31.4	33.4	2.0
Private-based worker (%)	59.4	54.8	−4.6	59.1	62.3	3.2
Presence of child (%)	53.5	55.2	1.6	43.0	46.3	3.3
Married/live-in partner (%)	53.3	57.1	3.8	49.8	59.6	9.9

[a] Change (%)=2009 (%)–2006 (%).
[b] University degree reflects individuals who obtained college/university degree or higher.
[c] Difference between percentages in the 2006 samples (Greater Stavanger vs. Back Yard) is statistically significant at <0.001.
[d] Difference between percentages in the 2009 samples (Greater Stavanger vs. Back Yard) is statistically significant at <0.001.

sample) and individuals living outside the 1 km circle (i.e., the Greater Stavanger sample). Back Yard respondents are those from the Forus area—an area which consists of residential houses mixed with industrial and business neighbourhoods. The Greater Stavanger respondents were mostly from the municipalities of Stavanger, Sandnes, Sola and Randaberg (see Fig. 2). The majority of the question lists distributed in both surveys were practically similar,[1] and the question format was based on the previous work of O'Garra et al. [23]. The surveys recorded information about socio-demographic characteristics as well as knowledge, attitudes and acceptance related to hydrogen vehicles and refuelling stations. However, questions about opinions of other sustainable vehicles were included in the second survey, along with personal reasons underlying such decisions to choose the particular energy features. The questions on environmental attitude and knowledge were further improved in the latter phase of the survey to acquire richer information related to social and psychological issues of hydrogen energy introduction. As the final target, for each survey, 400 completed interviews from the Back Yard sample and 600 interviews from the Greater Stavanger sample were successfully recorded, resulting in a total of 2000 interviews being recorded in the 2006 and 2009 phases. This data collection method did not record the response rate (i.e., the ratio between the number of persons who agreed to participate in the survey and the number of persons who were approached). The empirical results are tabulated and figured in the next section.

4. Changes in attitude, knowledge and acceptance related to hydrogen energy features

4.1. Sample profile

Table 1 summarises the proportions of the samples in the two phases of the survey, primarily considering socio-demographic attributes. The analyses for the Greater Stavanger sample are based on weighted data, while the Back Yard sample was not weighted as population characteristics of the Back Yard area are difficult to obtain. In general, the sample size was consistent between the 2006 and 2009 phases and between the Back Yard and the Greater Stavanger samples. Chi-square tests of our preliminary results confirmed that only the percentages of 'full-time worker' differed significantly in the two samples; such

[1] Detailed descriptions about the first survey approach can be found in Thesen and Langhelle [15].

evidence was consistently found in both phases. Overall, several notions about the dataset profile can be summarised as follows:

- Compared to the first survey phase, female participation in the second phase slightly decreased in the Back Yard (−5.0%) and the Greater Stavanger (−7.3%) samples.
- The proportions of individuals with access to private autos are high (greater than 90%) in both sample groups, but slightly increased from 2006 to 2009. These results are consistent with the trends reported by Statistics Norway, where an increase in auto ownership has shaped all major cities in Norway, including Greater Stavanger, over the last few decades.
- The proportions of full-time workers decreased slightly in both sample groups (−2.3% in the Back Yard and −3.6% in Greater Stavanger). However, such changes seem to vary across work types. For instance, the proportions of petroleum and private-based workers increased in the Back Yard sample (3.2%) but decreased in the Greater Stavanger sample (−4.6%).
- Very little change occurred in household structure in either the Back Yard or Greater Stavanger samples between the two survey phases.

4.2. Pro-environment attitudes

As briefly mentioned in the literature review, measuring attitudes about the natural environment and urban sustainability is essential due to their crucial role in influencing public opinions to support (or decline) sustainable energy features. In the 2006 and 2009 phases, all respondents were asked to rate their levels of pro-environment attitudes. Four-item Likert-type attitude statements were provided with five possible answers: *fully disagree*, *disagree*, *neither agree nor disagree*, *partly agree* and *fully agree*. To determine whether statistically significant differences emerged in responses across both phases of survey, the Mann–Whitney *U*-test and the Kolmogorov–Smirnov test were applied (see Table 2).

The results clearly indicate that respondents who accepted (*partly* and *fully agree*) statement 1 ('Solving environmental problems should be one of the top three priorities for public spending') decreased between 2006 and 2009 in both sample groups (−15% in the Greater Stavanger and −19% in the Back Yard sample). The Mann–Whitney *U*-tests further confirmed statistically significant differences between the 2006 and 2009 data in terms of public opinions related to statement 1. Such evidence was consistently obtained in the Greater Stavanger and Back Yard cases.

Statement 2 discussed whether it is necessary for everyone to engage in certain activities to protect the environment. The results indicated that the majority of respondents supported (*partly agree* or *fully agree*) this statement (more than 50% in both phases and both sample groups). Again, the trends in supporting this statement decreased over time (−23% in the Greater Stavanger sample and −25% in the Back Yard sample). Such changes were further statistically confirmed through the Mann–Whitney *U*-tests and the Kolmogorov–Smirnov tests, demonstrating that respondents' attitude regarding statement 2 differed between 2006 and 2009. These results were consistent in the two sample groups.

The third statement is: 'Science and technology are keys to solving environmental problems in Norway.' The results indicated that approximately 32–37% of the total respondents supported (*partly* or *fully agree*) this statement in 2006 and 2009, with small temporal changes occurring (−4% in the Greater Stavanger sample and −6% in the Back Yard sample). Although the Kolmogorov–Smirnov tests confirmed differences of respondents' attitude concerning statement 3 between 2006 and 2009, the Man–Whitney *U*-tests failed to confirm such differences for the Back Yard case ($p < 0.094$, at the 0.05 significance level).

The last statement asked respondents whether environmental problems, like global warming and air pollution, have been exaggerated (statement 4). Approximately two thirds of total respondents accepted (*partly* or *fully agree*) the statement; the percentages decreased between 2006 and 2009 (−10% in the Greater Stavanger sample and −17% in the Back Yard sample). The Kolmogorov–Smirnov tests confirmed these findings, suggesting statistically significant differences between the two survey phases concerning respondents' opinions of statement 4. Such differences were found in the Greater Stavanger and Back Yard groups.

Overall, it can be concluded that more than 30% of respondents supported (*partly agree* or *fully agree*) pro-environment attitudinal statements (exceeding 50% in several cases) based on the 2006 and 2009 surveys. In addition, there was a strong indication that the percentages of those who supported the attitudes had changed and decreased over time. These results were statistically confirmed for most cases. Such changes are expected to influence the trends of public acceptance of support for hydrogen vehicles.

4.3. Hydrogen knowledge

Respondents were asked to indicate the level of their knowledge about hydrogen fuels, with five possible answers: *very much*, *quite a bit*, *neither a lot nor a little*, *quite a little* or *very little or nothing*. As Fig. 3 demonstrates, in general, the proportions of individuals who answered *very much* or *quite a bit* about hydrogen vehicles and its fuels increased from 2006 to 2009. For example, the proportions of individuals with *very much knowledge* slightly increased in the Greater Stavanger and the Back Yard sample. The proportions of *quite a bit of knowledge* about hydrogen vehicles substantially increased, particularly in the Greater Stavanger sample. The proportions of *neither a lot nor a little* also increased

Table 2
Environmental attitudes (*partly* or *fully agree*).

	Greater Stavanger					Back Yard				
	2006 (%)	2009 (%)	Change (%)	Mann Whitney *U*-test	Kolmogorov–Smirnov test	2006 (%)	2009 (%)	Change (%)	Mann Whitney *U*-test	Kolmogorov–Smirnov test
Solving environmental problems should be one of the top 3 priorities for public spending	80	65	−15	0.000	0.000	84	65	−19	0.000	0.000
It is necessary for everyone, including myself and my family, to engage in certain activities to protect the environment	79	56	−23	0.000	0.000	77	52	−25	0.000	0.000
Science and technology are the key to solving environmental problems	37	33	−4	0.000	0.003	38	32	−6	0.094 (n.s.)	0.010
Environmental problems (e.g., global warming and air pollution) have been exaggerated	85	75	−10	0.115 (n.s.)	0.010	89	72	−17	0.000	0.000

The significance level is 0.05.

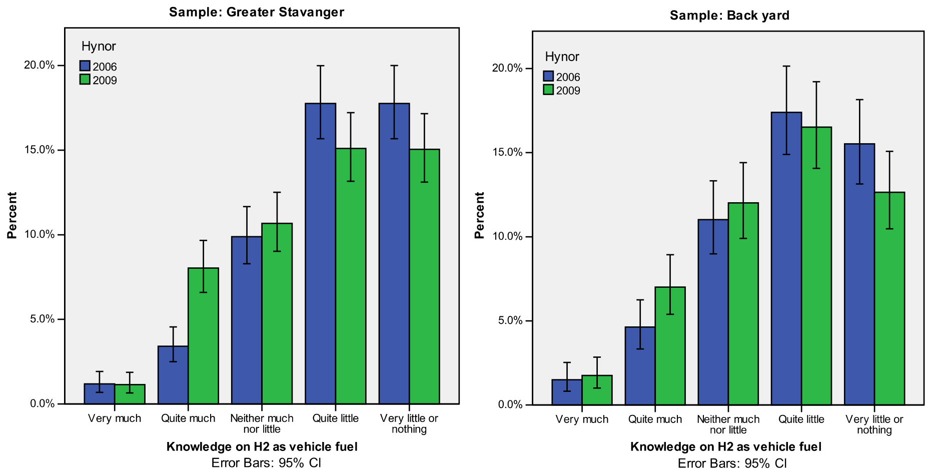


Fig. 3. Public knowledge of hydrogen vehicles.

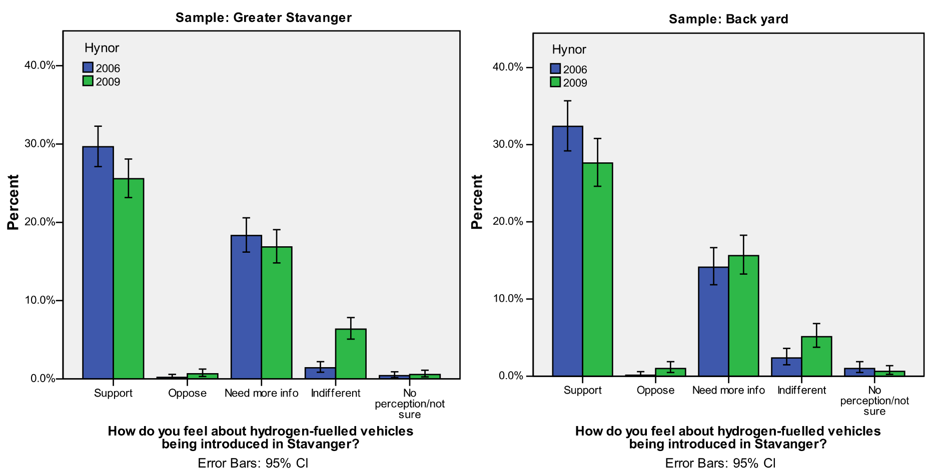


Fig. 4. Public acceptance of hydrogen vehicles.

Table 3
The possibility of using hydrogen fuels and willingness to pay for hydrogen fuels.

		Greater Stavanger			Back Yard		
		2006	2009	Change	2006	2009	Change
The possibility of replacing hydrogen as the main vehicle fuel	Very positive	46.5	31.4	–15.2	57.4	28.1	-29.3
	Quite positive	36.0	38.6	+2.6	30.1	42.2	+12.1
	Neither positive or negative	15.1	24.4	+9.3	10.9	24.9	+14.0
	Quite negative	1.8	2.9	+1.1	0.8	3.2	+2.4
	Very negative	0.5	2.6	+2.1	0.8	1.6	+0.8
Willingness to pay more for hydrogen fuels	No, I would not pay	38.4	43.8	+5.3	45.2	44.1	–1.1
	Yes, a little more	56.4	51.4	–4.9	49.7	52.2	+2.5
	Yes, much more	5.2	4.8	–0.4	5.1	3.7	–1.4

over time in both locations: 2.1% in the Back Yard sample and 3.5% in the Greater Stavanger sample.

4.4. Public acceptance and WTP for hydrogen fuels

Respondents' opinions about the introduction of hydrogen vehicles in Greater Stavanger were further elaborated upon by asking about their levels of acceptance of the technology (Fig. 4). They were given four choices to answer the statement: *support*, *oppose*, *need more information* and *indifferent*. Surprisingly, the results suggest that those who *support* hydrogen technology decreased over time in Greater Stavanger and Back Yard. In contrast, respondents who are *indifferent* to hydrogen-fuelled vehicles increased by 10% (the Greater Stavanger sample) and 5.5% (the Back Yard sample). The proportions of *oppose* to this issue also slightly increased in both sample groups.

The next step was to check whether the respondents were willing to replace their current vehicles with hydrogen vehicles (see Table 3). Note here that this question specifically targeted those who had personal vehicles. The results indicated that the proportions of *very positive* reaction to this statement substantially decreased in the Back Yard (–29.3%) and Greater Stavanger samples (–15.2%) from 2006 to 2009. However, the percentages of *quite positive* increased over time; this trend was much more obvious among the Back Yard sample (12%). The Kolmogorov–Smirnov tests confirmed differences in relation to the willingness to replace current vehicles with

hydrogen vehicles between 2006 and 2009 in both the Greater Stavanger ($p<0.001$) and Back Yard ($p<0.001$) samples.

Finally, the surveys measured WTP for hydrogen fuels. No final consensus emerged about the trends of public opinions regarding WTP for hydrogen fuels since the descriptive results show inconsistent trends between group samples and across categories. For example, the shares of the total sample who indicated that they would not pay declined in the Back Yard sample (−1.1%), but increased in the Greater Stavanger sample (5.3%). In contrast, the number of Back Yard respondents who claimed that they would pay a little increased (2.5%) whereas the number of Greater Stavanger respondents slightly decreased (−4.9%).

5. Changes in hydrogen vehicles' acceptance

A set of statistical estimations using Multinomial Logistic Regression (MLR) was further carried out as the next step in the analysis, aimed at examining factors likely to influence public acceptance of hydrogen vehicles' applications and explaining how such relations have changed over time. In addition, the MLR approach was considered due to the nature of nominal (unordered) categories in the dependent variable (support, oppose, need more information and indifferent). The independent variables include socio-demographic characteristics, knowledge about hydrogen vehicles and refuelling stations as well as public attitudes towards a sustainable environment. The list of names and definitions of explanatory variables used in this analysis is presented in Table 4 while the results are shown in Table 5. The model estimations performed the full-information maximum-likelihood procedure using the 2006 and 2009 datasets.

Table 4
Explanatory variables in multinomial logistic regression models.

Age	Respondent's age
Backyard	Dummy for sample; 1=Back Yard, 0=Greater Stavanger
Worker	Dummy for working status; 1=Worker, 0=non worker
Male	Dummy for gender; 1=male, 0=female
Child	Dummy for children; 1=children, 0=no children
Carown	Number of cars in household
H2FUEL	Degree of knowledge about hydrogen as a fuel, from 1=very little or nothing to 5=very much
H2VEH	Degree of knowledge about hydrogen vehicles can be used in Stavanger, from 1=very little or nothing to 5=very much
ATT1	Attitudes to statement: 'Solving environmental problems should be one of the top 3 priorities for public spending'
ATT2	Attitudes to statement: 'It is necessary for everyone, including myself and my family, to engage in certain activities for protecting the environment'
ATT3	Attitudes to statement: 'Science and technology are the key to solving environmental problems'
ATT4	Attitudes to statement: 'Environmental problems, like global warming and air pollution, have been exaggerated'

Before discussing the estimated results, the fit of models is first elaborated. The 2006 model indicates good Pseudo R^2 values: Cox and Snell R^2 value of 0.222, Nagelkerke R^2 value of 0.280 and a McFadden R^2 of 0.160. A value of 0.222 reported by Cox and Snell R^2 indicates that approximately 22% of the variation in the dependent variable related to the public preferences for hydrogen vehicles can be explained by the variation in the explanatory variables. A similar interpretation can also be made for other R^2 values. For the 2009 model, higher values of Pseudo R^2 are even greater: Cox and Snell $R^2=0.335$, Nagelkerke $R^2=0.386$ and McFadden $R^2=0.201$. In the preliminary analysis, we omitted certain independent variables with high multicollinearity by checking the variance inflation factor (VIF) values. Basically, no formal 'cut-off' value exists for use with VIF to determine whether multicollinearity exists. However, values of VIF in excess of 2.5 are often suggested as indicating multicollinearity in logistic regression analysis studies. The final results in Table 5 indicate that all independent variables used in the model systems had a VIF value lower than 2.5, meaning that our MLR models have a goodness of fit in relation to the independent variables.

The estimated results suggest that individuals living close to hydrogen refuelling stations (i.e., the Back Yard sample) are more likely to support hydrogen technology features than those who live beyond the stations based on the 2006 model (B: 0.365; $p<0.001$). This evidence is line with two studies from Greater Stavanger [15,16] and London [21,23], which report that living close to refuelling stations could generate a kind of curiosity for hydrogen-related projects as the residents would be more aware of the positive objectives of the projects, implying that they are likely to support hydrogen vehicles and refuelling stations' developments. However, our results demonstrated such relationships occur inconsistently over time as the Back Yard variable does not statistically imply support for hydrogen technology in the 2009 model (B: 0.442; $p<0.100$). One possible explanation for these results is that the introduction of a new sustainable technology can attract attention

Table 5
Predicting support for the introduction of hydrogen vehicles in Greater Stavanger.

	2006						2009					
	Support		Oppose		Indifferent		Support		Oppose		Indifferent	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Age	−0.005	0.006	0.049	0.053	−0.034	0.014	−0.010	0.006	−0.023	0.025	−0.009	0.009
Backyard	0.365**	0.170	−0.422	1.462	1.299**	0.442	0.045	0.170	0.393	0.643	−0.167	0.250
Worker	0.062	0.208	0.755	1.722	−1.096	0.465	0.234	0.199	−0.315	0.723	−0.405	0.269
Male	0.950***	0.175	−0.726	1.739	1.241**	0.470	0.708***	0.174	−0.115	0.835	0.700***	0.255
Child	−0.143	0.181	0.319	1.495	−0.226	0.453	−0.230	0.181	0.223	0.720	−0.433	0.267
Carown	−0.024	0.121	−0.232	1.020	−0.139	0.286	0.044	0.118	-0.034	0.457	−0.063	0.167
H2FUEL	0.463***	0.097	2.517	0.936	0.126	0.241	0.431***	0.084	0.820**	0.289	0.40***	0.115
H2VEH	0.934***	0.241	2.593	2.028	1.010	0.670	0.788***	0.103	1.918***	0.393	0.192	0.131
ATT1	0.193**	0.089	0.392	0.595	0.303	0.189	0.021*	0.093	0.101	0.327	0.386***	0.123
ATT2	0.027	0.058	−0.610	0.482	−0.336*	0.166	0.119	0.084	0.155	0.335	0.048	0.116
ATT3	0.048	0.086	−0.815	0.779	0.148	0.198	−0.033	0.066	0.129	0.241	0.129	0.095
ATT4	−0.110	0.086	0.797	0.519	0.261	0.191	−0.087	0.089	−0.227	0.331	−0.205*	0.120
CONSTANT	3.624***	0.696	−1.295	5.384	−0.862	1.662	4.202***	0.827	−4.235	3.200	2.654	1.121

Note: The reference category for the dependent variables is to want more information.

* $p<0.1$ $N=1000$ for each model.

** $p<0.05$.

*** $p<0.01$.

Table 6
Predicting willingness to spend extra money to use hydrogen fuels.

	2006				2009			
	B	SE	Wald	Exp (B)	B	SE	Wald	Exp (B)
Age	−0.032***	0.011	8.207	0.969	−0.001*	0.012	0.003	1.001
Backyard	−0.081	0.324	0.062	0.922	−0.099	0.366	0.073	0.906
Worker	−0.401	0.367	1.194	0.670	−0.677*	0.387	3.070	0.508
Male	0.156	0.342	0.208	0.856	1.488***	0.395	1.420	4.427
Child	−0.105	0.336	0.098	0.900	−0.043	0.395	0.012	0.958
Carown	−0.028	0.224	0.015	0.973	−0.203	0.247	0.675	0.816
H2FUEL	0.417	0.158	6.914	0.659	0.188	0.163	1.337	1.207
H2VEH	0.115	0.516	0.050	1.122	0.072	0.193	0.138	1.074
ATT1	0.602**	0.254	5.616	0.548	0.895**	0.292	9.386	2.446
ATT2	0.197	0.125	2.502	1.218	0.422*	0.223	3.592	1.525
ATT3	−0.198	0.199	0.993	0.820	−0.074	0.133	0.311	0.929
ATT4	0.239	0.151	2.504	1.270	0.003	0.197	0.001	1.003
Constant	1.038	1.355	0.587		−9.026***	2.006	2.024	
Nagelkerke	0.192					0.221		

$N = 1000$ for each model.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

and curiosity among residents who live close to the development during the initial development phase, making them more likely to support the technology. However, after a certain period of time, the Back Yard issue becomes irrelevant as the public – regardless of where they live – becomes more familiar with and knowledgeable about hydrogen vehicles and their development progress.

Several social variables were used in the model analysis, but only the gender variable was statistically related to support for hydrogen vehicles in both periods. This result indicates that being a male would imply support or indifference for the introduction of hydrogen in 2006 and 2009 (0.950 and 0.708, respectively). This evidence seems to support a wealth of previous research, reporting that males have greater concern about and awareness of sustainable vehicle-related issues than their female counterparts. Small decreases found here may suggest that gender influence affecting public preference for hydrogen vehicles weakens over time. Females have likely become more familiar with hydrogen vehicles and other sustainable energy debates in society in recent years.

The results of the study further reveal that, as expected, greater knowledge about hydrogen fuels (H2FUEL) and hydrogen vehicles (H2VEH) imply greater support for the introduction of hydrogen energy developments; these results are relatively stable over time. Furthermore, over time, an increase in hydrogen technologies' knowledge could also lead the public to be more likely to oppose and be indifferent to hydrogen vehicle developments.

Across all pro-environment attitudes' variables, the estimated results suggest that only ATT1 ('Solving environmental problems should be one of the top 3 priorities for public spending') has a significant and positive association with the result in supporting hydrogen vehicles and refuelling stations over the three-year period (B: 0.193; $p < 0.05$ [2006] and B: 0.021; $p < 0.1$ [2009]). An obvious interpretation driven by these findings is that ATT1 is very reliable for use as an indicator to test the effects of a pro-environment attitude on hydrogen acceptance. This also means that such a variable needs to be incorporated when one aims to model public acceptance of hydrogen energy developments or other sustainable energy for future research.

6. Changes in willingness to pay for hydrogen fuels

This final analysis utilised binary logistic regression analysis to explain WTP for hydrogen fuels. In our original dataset, the dependent variable of the model system consists of three groups: 'Yes, much more', 'Yes, a little more' and 'No, I would not pay'. Since the small proportion of 'Yes, much more' was obtained in the survey, we recoded the dependent variables with a dummy variable ('Yes' or 'No'). This modification further enabled us to obtain straight results about public preference to purchase hydrogen fuels.[2] These analyses were performed using the full information maximum-likelihood procedure and also incorporated the values of VIF in excess of 2.5 to indicate multicollinearity. The final results are tabulated in Table 6.

The estimation results indicate that younger individuals are more likely to indicate WTP for hydrogen fuels than older individuals; this evidence is evident throughout the observed periods. This result presumably stems from the fact that young individuals have greater access to information (e.g., from school or university) about the needs to reduce emission actions and negative consequences of using conventional fuels. Although being male has no significant impact on WTP for hydrogen fuels in the 2006 model, this result changed in the 2009 model as males were positively related to WTP for hydrogen fuels. Working individuals were less likely to pay more for hydrogen fuels in the 2009 model, but no similar evidence was captured in the 2006 model. It is hard to explain without further investigation why such relationships were only shown in the 2009 model. However, it is reasonable to conclude that males and workers are those who are much more likely to spend extra money on hydrogen fuels.

Although we anticipated that knowledge about hydrogen vehicles might be linked to the likelihood of WTP for hydrogen fuels, no such evidence was reported in our estimation results. In addition, the estimation results show that a greater value of pro-environment attitude (ATT1) can imply the likelihood of WTP in purchasing hydrogen fuels; such results were consistently found in both observed periods.

7. Discussions

This paper has sought to explore temporal changes concerning attitudes, knowledge and acceptance as well as WTP related to

[2] However, we acknowledge potential problems in this approach as this study may neglect valuable information underlying decisions of willingness to pay much more and willingness to pay a little more for hydrogen fuels. Addressing and incorporating this information into the analysis offer a direction for future research.

hydrogen vehicles among Greater Stavanger individuals. The analysis was conducted using two survey phases in 2006 and 2009 among those who live very close to refuelling stations (Back Yard) and those who live beyond the stations (Greater Stavanger). The analysis was conducted in light of the fact that Norwegian newspapers have consistently published the progress made on hydrogen vehicles and fuels for the public.

The descriptive results suggest that public knowledge about hydrogen fuels and vehicles differed between 2006 and 2009, indicating positive trends. Intuitively, information about hydrogen energy improvements during the three-year period seems likely to contribute to the growing knowledge among the respondents. This may be relevant to what Qu et al. [32] reported—namely, that more people become knowledgeable about the importance of sustainable energy through informal means, such as newspapers and the Internet. However, the role of information in increasing knowledge levels and public acceptance of hydrogen vehicles was not tested due to the limitation of our data. For example, no evidence in our dataset indicated how often respondents had read or heard about hydrogen energy from various means (e.g., the Internet, radio, TV and newspaper) or how such means could be related to improving their knowledge. Determining which types of information have enhanced knowledge about hydrogen vehicles and fuels and which types would not improve public knowledge needs to be studied further [22,26]. This aspect should be included in future surveys to gain a better understanding about the effects of information on changing public knowledge as well as public acceptance.

The descriptive results and statistical tests indicate that respondents' pro-environment attitudes have decreased over time. For example, the number of those who agreed (*partly* or *fully agree*) that everyone should engage in certain activities to protect the environment decreased substantially over time; these findings were detected in both sample groups. Similarly, the number of respondents who supported hydrogen vehicles' introductions and indicated a great willingness to pay for hydrogen fuels decreased between 2006 and 2009. The multivariate analyses suggest a few key points in the temporal changes of the public's attitudes, knowledge, acceptance and WTP related to hydrogen vehicles. According to the results, an increase of hydrogen-related knowledge can imply greater support for hydrogen vehicles; these relationships were consistently reported in 2006 and 2009 and are in line with previous studies (e.g., [24]). Interestingly, we found that gaining more knowledge can also lead to greater opposition and indifference to the technology. Past studies reveal that users identified current and potential barriers to the technology [34], infrastructure availability [33] and the current price of fuels [11] as issues which could push them to be more realistic about the impact of the technology, making them less supportive of this energy type.

No evidence was found in the estimation results to support the relationships between knowledge and WTP for hydrogen fuels, but significant relationships were found between attitudes and WTP for hydrogen fuels. These results differ from public acceptance models, demonstrating that levels of knowledge and attitudes statistically implied greater public acceptance of hydrogen vehicles. Thus, the results seem to explain that improving public knowledge can increase the propensity of public acceptance of hydrogen vehicles and refuelling stations. However, improving public attitudes to be more supportive of the natural environment is a powerful approach to influencing not only public acceptance of hydrogen vehicles, but also WTP for hydrogen fuels. These findings were consistently found in the observed periods.

Regarding the effects of socio-demographic characteristics on the propensity to influence public acceptance and WTP for hydrogen fuels, the results indicated that living closer to hydrogen refuelling stations may influence the likelihood to support hydrogen vehicles in the 2006 data. However, such a relationship did not exist in the 2009 data. Past studies, like O'Garra et al. [21,23], Thesen and Langhelle [15], and Tarigan et al. [16], have strongly considered the Back Yard effect for explaining public acceptance of hydrogen energy. However, based on the current study, it seems that the Back Yard effect on hydrogen acceptance is weaker on a temporal basis. Meanwhile, being male consistently affected the likelihood of hydrogen acceptance, although the effect values were smaller between the 2006 and 2009 models. A large number of previous studies also stressed the role of male individuals in supporting sustainable energy developments; our data confirm such previous results.

A few possible insights can be drawn regarding negative trends of attitudes and acceptance of hydrogen vehicles in Greater Stavanger. First, we observed that, in the field, the development of hydrogen projects has been quite slow in Greater Stavanger. Since 2009, when the second survey was conducted, only a few hydrogen vehicles and one hydrogen refuelling station were available in Greater Stavanger, suggesting that local residents have less opportunity to have personal experiences with hydrogen vehicles. Martin et al. [11], Shaheen et al. [24] and others have clearly shown that direct experience like driving and riding in vehicles can increase public awareness about the technology. Furthermore, a set of examples from different cities in the world [35–39] indicate that the introduction of public buses and taxis [38] that use hydrogen energy may generate more confidence among passengers, thereby creating loyalty to re-use this mode in the future. Such results can illustrate how direct experiences are crucial for generating more support within the community.

Furthermore, since the HyNor project was launched, no additional development of hydrogen refuelling stations within the Greater Stavanger region has occurred, which could therefore contribute to the lack of confidence among local residents about the progress of this technology. In contrast, other sustainable fuels are becoming much more known in Greater Stavanger. For example, the presence of electric cars is rapidly increasing in Greater Stavanger and Norway, and it has been reported that the total number of electric cars has increased to more than 1000 since the first vehicle sold in 1998 in Norway (www.puremobility.no). In addition, a growing number of parking area developments have occurred dedicated exclusively to electric vehicles within the city centre. There is further evidence that biogas (biomethane)-powered taxis are becoming common in Greater Stavanger and are often used by residents for their mobility. The experience of riding in a biogas taxi is expected to increase public awareness, acceptance and probably confidence about these green modes. Unfortunately, such progress did not appear in the hydrogen energy case; over time, this might contribute to the decrease of public support and WTP for hydrogen fuels.

In the context of political discourses related to hydrogen energy developments in Norway, Sataøen [14] stressed the lack of vision of the Norwegian HyNor project that, in the long term, may affect the fall of HyNor projects. This study reports that the sustainability of the HyNor project has been called into question by certain stakeholders in Greater Stavanger as the HyNor project's visions changed from an optimistic approach to a less optimistic and even pragmatic approach between 2006 and 2008. This change was probably due to the fact that expectations concerning support from the partners (auto industries, policymakers and research groups) in the HyNor project were not fulfilled. For example, auto industries seem to be concerned about the commercial value of hydrogen vehicles. Furthermore, practically, limited innovation has been proposed by the authorities regarding tax credits, subsidies and other incentives to reduce the net purchase price of hydrogen vehicles and fuels as well as other technological problems. Such examples may indicate

that – along with engineering improvements for hydrogen technology – serious attention should be focused on social aspects of the HyNor project.

8. Future research and conclusion

A few notes concerning our study should be considered for future research efforts. First, it must be repeated here that future studies need to elaborate upon the effects of information on knowledge, attitudes and acceptance related to hydrogen vehicles. As suggested by Molin [22], information could influence residents' preferences about hydrogen vehicles; this needs further clarification for the Norwegian context through an in-depth investigation. Second, the availability of more detailed information about the challenges faced by the public when riding in or considering hydrogen vehicles should be empirically examined to extend investigations regarding, for example, hydrogen fuel endurance, vehicle speed, distance to reach the stations and maintenance issues when purchasing the vehicles as well as other hidden problems that could decrease hydrogen acceptance. Finally, the next avenue of our study as part of our research plans in the HyNor project aims to incorporate a cluster analysis approach considering public preference, attitudes' characteristics and knowledge about the technology. The results could identify those who can more flexibly shift to using hydrogen vehicles and those who cannot. Such research would further indicate the groups of individuals with very positive perceptions of hydrogen fuels and those without such perceptions. This analytical approach is critical for proving feedback for effective campaigns and other efforts in order to promote hydrogen vehicles and refuelling stations.

Overall, this study reports that public knowledge of hydrogen vehicles among the Greater Stavanger respondents increased between 2006 and 2009. However, attitudes and acceptance related to hydrogen technology substantially decreased during the observed periods. Knowledge about a sustainable environment can affect the acceptance of hydrogen energy. However, the level of pro-environment attitudes can increase not only the public's acceptance of hydrogen vehicles, but also their willingness to pay for hydrogen fuels. These results were consistently found over the observed periods, based on the Greater Stavanger's case.

References

[1] Dunn S. Hydrogen futures: toward a sustainable energy system. International Journal of Hydrogen Energy 2002;27(3):235–64.

[2] Farrell AE, Keith DW, Corbett JJ. A strategy for introducing hydrogen into transportation. Energy Policy 2003;31(13):1357–67.

[3] Sobrino FH, Monroy CR, Pérez JLH. Critical analysis on hydrogen as an alternative to fossil fuels and biofuels for vehicles in Europe. Renewable and Sustainable Energy Reviews 2010;14(2):772–80.

[4] Stiller C, Bünger U, Møller-Holst S, Svensson AM, Espegren KA, Nowak M. Pathways to a hydrogen fuel infrastructure in Norway. International Journal of Hydrogen Energy 2010;35(7):2597–601.

[5] McDowall W, Eames M. Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: a review of the hydrogen futures literature. Energy Policy 2006;34(11):1236–50.

[6] Abbasi T, Abbasi SA. Renewable' hydrogen: prospects and challenges. Renewable and Sustainable Energy Reviews 2011;15(6):3034–40.

[7] Mazloomi K, Gomes C. Hydrogen as an energy carrier: prospects and challenges. Renewable and Sustainable Energy Reviews 2012;16(5):3024–33.

[8] Lim S, Lee KT. Implementation of biofuels in Malaysian transportation sector towards sustainable development: a case study of international cooperation between Malaysia and Japan. Renewable and Sustainable Energy Reviews 2012;16(4):1790–800.

[9] Bradley TH, Frank AA. Design, demonstrations and sustainability impact assessments for plug-in hybrid electric vehicles. Renewable Sustainable Energy Review 13, 2009:115–28.

[10] European Commision. Hydrogen energy and fuel cells—a vision of our future. Luxembourg: office for official publications of the European Communities 2003 (ISBN 92-894-5589-6).

[11] Martin E, Shaheen SA, Lipman TE, Lidicker JR. Behavioral response to hydrogen fuel cell vehicles and refuelling: results of California drive clinics. International Journal of Hydrogen Energy 2009;34(20):8670–80.

[12] US Department of Energy 2011. An integrated strategic plan for research, development and demonstration of hydrogen and fuel cell technologies 2012 〈http://www.hydrogen.energy.gov/pdfs/program_plan2011.pdf〉.

[13] Bjøkvoll S, Myklebust J, Skulason JB, Wennike F 2011. Preparing socio and economic evaluations of future H2 lighthouse projects. European commission 2011 (ec.europa.eu/research/fch/pdf/preparh2.pdf).

[14] Sataøen H Building the hydrogen highway: the visions of a large-scale hydrogen project in Norway. Sociological Research Online 13 (3) 7, 2008. 〈http://dx.doi.org/10.5153/sro.1716〉.

[15] Thesen G, Langhelle O. Awareness, acceptability and attitudes towards hydrogen vehicles and filling stations: a Greater Stavanger case study and comparisons with London. International Journal of Hydrogen Energy 2008;33(21): 5859–67.

[16] Tarigan AKM, Bayer SB, Langhelle O, Thesen G. Estimating determinants of public acceptance of hydrogen vehicles and refueling stations in Greater Stavanger. International Journal of Hydrogen Energy 2012;37(7):6063–73.

[17] Ogden JM, Steinbugler M, Kreutz T. A comparison of hydrogen, methanol and gasoline as fuels for fuel cell vehicles. Journal of Power Sources 1999;79(2): 143–68.

[18] Ogden JM. Developing a refuelling infrastructure for hydrogen vehicles: a southern California case study. International Journal of Hydrogen Energy 1999;24(8):709–30.

[19] Schulte I, Hart D, van der Vorst R. Issues affecting the acceptance of hydrogen fuel. International Journal of Hydrogen Energy 2004;29(7):677–85.

[20] Huijts NMA, Molin EJE, Steg L. Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework. Renewable and Sustainable Energy Reviews 2012;16(1):525–31.

[21] O'Garra T, Mourato S, Pearson P. Investigating attitudes to hydrogen refuelling facilities and the social cost to local residents. Energy Policy 2008;36(6): 2074–85.

[22] Molin E Causal analysis of hydrogen acceptance. Transportation Research Record 2005; 1941, 115–121.

[23] O'Garra T, Mourato S, Pearson P. Analysis awareness and acceptability of hydrogen vehicles: a London case study. International Journal of Hydrogen Energy 2005;30(6):649–59.

[24] Shaheen SA, Martin E, Lipman TE. Dynamics in behavioral response to fuel-cell vehicle fleet and hydrogen fueling infrastructure: an exploratory study. Transportation Research Record 2008;2058:155–62.

[25] Altmann M, Gräsel C The acceptance of hydrogen technologies, 1998.

[26] Schmoyer RL, Truett T, Cooper C Results of the 2004 knowledge and opinions surveys for the baseline knowledge assessment of the US Department of Energy Hydrogen Program. ORNL/TM-2006/417, Oak Ridge National Laboratory, Oak Ridge (TN), 2006.

[27] Noblet CL, Teisl MF, Rubin J. Factors affecting consumer assessment of eco-labeled vehicles. Transportation Research Part D: Transport and Environment 2006;11(6):422–31.

[28] Maak M, Nielsen KD, Torfason HT, Sverrisson SO, Benediktsson K Assessment of socio-economic factors with emphasis on: public acceptance of hydrogen as a fuel. ECTOS Deliverable 12. Available from: 〈http://www.vetni.is/newenergy/upload/files/utgefid_efni/ectos_12-assessement_of_socio-eco.pdf〉; 2011.

[29] Ricci M, Bellaby P, Flynn R. What do we know about public perceptions and acceptance of hydrogen? A critical review and new case study evidence International Journal of Hydrogen Energy 2008;33(21):5868–80.

[30] Roche MY, Mourato S, Fischedick M, Pietzner K, Viebahn P. Public attitudes towards and demand for hydrogen and fuel cell vehicles: a review of the evidence and methodological implications. Energy Policy 2010;38(10): 5301–10.

[31] Sherry-Brennan F, Devine-Wright H, Devine-Wright P. Public understanding of hydrogen energy: a theoretical approach. Energy Policy 2010;38(10): 5311–9.

[32] Qu M, Ahponen P, Tahvanainena L, Grittena D, Mola-Yudegoa B, Pelkonena P. Chinese university students' knowledge and attitudes regarding forest bio-energy. Renewable and Sustainable Energy Reviews 2011;15(8):3649–57.

[33] Sperling D, Kitamura R. Refueling and new fuels: an exploratory analysis. Transportation Research 1986;20(1):15–23.

[34] Schjølberg I, Østdahl AB. Security and tolerable risk for hydrogen service stations. Technology in Society 2008;30(1):64–70.

[35] Haraldsson K, Folkesson A, Saxe M, Alvfors P. A first report on the attitude towards hydrogen fuel cell buses in Stockholm. International Journal of Hydrogen Energy 2006;31(3):317–25.

[36] Saxe M, Folkesson A, Alvfors P. A follow-up and conclusive report on the attitude towards hydrogen fuel cell buses in the CUTE project—from passengers in Stockholm to bus operators in Europe. International Journal of Hydrogen Energy 2007;32(17):4295–305.

[37] Hickson A, Phillips A, Morales G. Public perception related to a hydrogen hybrid internal combustion engine transit bus demonstration and hydrogen fuel. Energy Policy 2007;35(4):2249–55.

[38] Mourato S, Saynor B, Hart D. Greening London's black cabs: a study of driver's preferences for fuel cell taxis. Energy Policy 2004;32(5):685–95.

[39] Heinz B, Erdmann G. Dynamic effects on the acceptance of hydrogen technologies—an international comparison. International Journal of Hydrogen Energy 2008;33(12):3004–8.